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ORIGINAL RESEARCH

RELIABILITY AND VALIDITY OF THE HIP ABDUCTOR ISOMETRIC ENDURANCE TEST: A NEW METHOD TO ASSESS THE ENDURANCE OF THE HIP ABDUCTORS

Joachim Van Cant, PT, PhD[1,2]
Christine Detrembleur, PT, PhD[3]
Philippe Mahaudens, PT, PhD[3]
Véronique Feipel, PT, PhD[2]

ABSTRACT

Background: Substantial deficits in the performance of the hip abductor muscles are reported in females with common lower extremity conditions. In this context, the hip abductor isometric test (HAIE) test has been developed to assess the endurance of the hip abductors.

Purposes: The aims of the study were: 1) to assess the test-retest reliability of the HAIE test and 2) to determine if the HAIE test is valid for the measuring hip abductor muscle fatigue.

Design: Diagnostic accuracy of clinical tests; test retest reliability and validity

Methods: Fifty-two healthy females, aged 18-30 years, were recruited. In two identical sessions, spaced by seven days, the participants performed the HAIE test and the test-retest reliability (ICC, SEM and MDC) was calculated. In ten subjects, surface EMG was used during the test in order to observe the change in the median frequency of EMG output of the gluteus medius and to determine if decrease of the median frequency is correlated with performance on the test, in order to discern validity.

Results: The HAIE test demonstrated good test-retest reliability (ICC = 0.84, SEM = 11.5 seconds and MDC = 32.8 seconds). Significant differences were noted between the average median frequency of participants for the last four fifteen second intervals ($p = 0.02$). Moderate correlation between MFslope and endurance time ($r = 0.56$, $p = 0.008$) and strong correlation between MFslope75s and endurance time ($r = 0.71$, $p = 0.001$) were found.

Conclusion: The results from this study support that the HAIE test is a reliable test for evaluating the endurance of the hip abductors. Further investigations should continue to explore the validity of the test, especially to determine which muscles limit the endurance time in healthy and unhealthy subjects.

Level of evidence: 2b

Key words: Hip abductor endurance, reliability, validity

[1] Department of Physical Therapy, Institut Parnasse-ISEI, Brussels, Belgium.
[2] Laboratory of Functional Anatomy, Faculty of Motor Sciences, Université Libre de Bruxelles, Brussels, Belgium.
[3] Institute of Neuroscience, Faculty of Motor Sciences, Université Catholique de Louvain, Brussels, Belgium.

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CORRESPONDING AUTHOR
Joachim Van Cant, PT, PhD
Department of Physical therapy, Institut Parnasse-ISEI, Avenue Mounier 85, 1200 Brussel, Belgium.
jvancant@yahoo.fr

INTRODUCTION

Substantial deficits in the performance of the hip abductor muscles, mainly in women, are reported in patients with common lower extremity conditions, such as patellofemoral pain (PFP), iliotibial band syndrome, anterior cruciate ligament injuries, and hip osteoarthritis.[1,2] Several authors have suggested that endurance deficit of the hip abductors could affect lower extremity movements in frontal plane and, therefore, increase joint stress during prolonged dynamic movements, like running.[3,4,5] However, while numerous tests are commonly used to assess the endurance capacity of specific muscles in healthy and symptomatic subjects (e.g. trunk extensors, neck flexors or ankle plantar flexors),[6,7,8] there are few tests that have been developed to assess the endurance of the hip abductors.[9] Thus, the hip abductor isometric endurance test (HAIE test) was developed to provide a standardized, easy to use evaluation of the endurance of the hip abductors.

In a clinical or research context, it is important to determine whether a specific endurance test is a reliable method for assessing muscle endurance. The test-retest reliability of a clinical test refers to the extent to which the test is consistent across time.[7] It is also crucial to determine the validity of an endurance test or, in other words, to identify whether muscle fatigue limits performance in terms of test endurance time or repetitions. Enoka and Duchateau[10] define muscle fatigue as the gradual decrease in the force capacity of muscle or the endpoint of a sustained activity and suggest to evaluate it by measuring a reduction in muscle force, a change in electromyographic activity or an exhaustion of contractile function.[10] In this respect and even if, at this stage, no consensus exists on the best way to evaluate muscle fatigue, the electromyographic (EMG) spectrum analysis is a specific way to assess this muscle impairment.[11,12,13,14] In the case of EMG, fatigue is defined as a decrease of the median frequency of the EMG power spectrum.[11]

Thus, the aims of the present study were: 1) to assess the test-retest reliability of the HAIE test and 2) to determine if the HAIE test is a valid test for the measuring hip abductor muscle fatigue. In this context, surface EMG was used during the test in order to observe the change in the median frequency of the gluteus medius (Gmed) and to determine if decrease of the median frequency is correlated with performance of the test (endurance time) in order to establish validity. Because previous studies suggest that hip muscle impairments are more prevalent in females than in males,[3,15] only females were recruited to participate in this study.

METHODS

Subjects

Fifty-two healthy females, aged 18-30 years, were recruited among students of the University of Louvain, Brussels, Belgium. The inclusion criteria were to be free of recent lower limb injuries (in the prior six months). The exclusion criteria were to have no history of orthopedic injury of or surgery performed on the lower limb or low back for in the prior 12 months and no cardiovascular, pulmonary, neurological, or systemic conditions.

All subjects gave written consent to participation in the study, which was approved by the Hospital and Departmental Ethics Committee, Saint-Luc - UCL (Brussels).

Procedures

The participants attended two assessment sessions, separated by seven days, and conducted by the same investigators (two physical therapists, under the direct supervision of a physical therapist with over 10 years of clinical experience). For procedural standardization, each investigator performed the same tasks in both sessions for all participants. At the second session, the investigators were not blinded to prior data**.** In both sessions, all subjects performed a five-minute sub-maximal warm-up on a stationary cycle and then performed the HAIE test with the dominant limb (defined as the limb used for kicking a soccer ball). At the first session, participant demographics and characteristics including age, weight, body mass, and physical activity levels were collected. To assess physical activity levels, the French version of the Baecke Activity Questionnaire (BAQ), validated by Bigard and Dufaurez,[3] was completed. The BAQ is a short questionnaire including a total of 16 questions classified into three domains receiving a score from one to five: work, sports, and non-sports leisure activity.[3] At the second session,

Table 1. *Demographic and clinical characteristics of the study sample (n = 52).*						
	Age (years)	**Height (cm)**	**Body mass (kg)**	**BAQ (Work)**	**BAQ (Sport)**	**BAQ (Free-time)**
Mean	23.2	163.2	58.7	2	2.9	3.5
SD	2.3	6.4	7.3	0.5	0.8	0.6

SD= standard deviation; BAQ= Baecke Activity Questionnaire

in order to assess the validity of the HAIE test, the EMG activity of the GMed was recorded during the test in ten subjects, randomly selected from among all the participants.

Demographic and clinical data are presented in Table 1.

The HAIE test

The subject was placed in a side lying position on the examination table with the hip to be evaluated placed superiorly in neutral alignment and with the pelvis stabilized by straps. The opposite limb was flexed at the hip and knee. The hand of the ipsilateral upper limb was placed on the pelvis. (Figure 1). Considering that previous studies showed that the muscle contractions elicited by tests evaluating isometric endurance, such as the "Sorensen test", were found to be equal to 40–52% of the maximal voluntary contractile force,[11,12] external weight, corresponding to 7.5% of body mass, was placed on the ankle of the evaluated limb.[9] Given that maximal isometric strength of hip abductors in side lying position ranges from 14% to 22% of body mass, 7.5% of BW corresponds to a percentage ranging from 34 % to 53% of the maximal voluntary contractile force.[16]

Upon verbal command, the subject was instructed to isometrically hold the limb in a horizontal position, aligned with the trunk, knee extended and to stabilize the pelvic and scapular girdles in a neutral position. In order to control for the horizontality of the leg, a horizontal bar, fixed to vertical bars, was placed 5 cm underneath the malleolus. Moreover, a mirror was positioned close to the examination table so that the participants could control the horizontal position of the limb during the test. Every 15 s and at the end of the test, the subject was asked to give an overall perception about how hard the exercise felt according to the Borg Rating of Perceived Exertion Scale (Borg RPE), a 15-point single-item scale

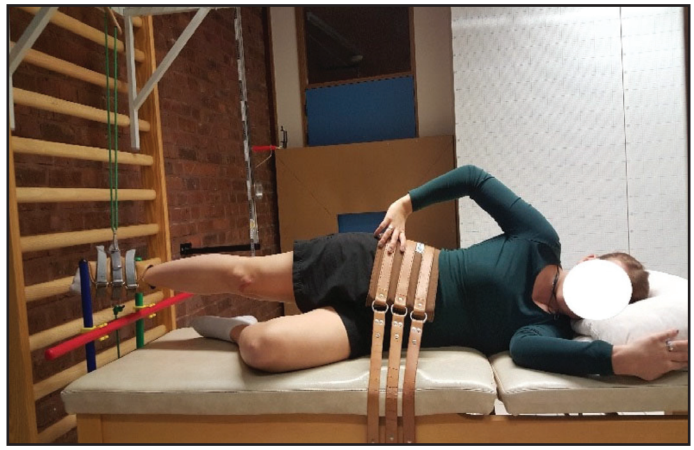

Figure 1. *The Hip Abduction Isometric Endurance (HAIE) test.*

ranging from 6 to 20 (with anchors ranging from 6 "No exertion" to 20 "Maximum exertion").[17]

The time during which the subject held the limb straight and the test was stopped when the participant could no longer control the horizontal posture (sustained contact with the bars for more than 5 s) despite investigator warnings or until she reached the limit of fatigue. Standardized instructions and verbal encouragement were given by the same investigator to all participants. Verbal encouragement consisted of the investigator giving positive verbal commands, every 15 s, encouraging the subject to hold the limb in a horizontal position and included the following sentence: "come on, let's keep going".

Equipment

The EMG signals of GMed were recorded by a telemetry EMG system (Telemg, BTS, Milan, Italy). One pair of circular surface electrodes (Medi-Trace, Graphic Controls Corporation, NY, USA) with an electrical surface contact of 100 mm2 were attached using tape to the GMed. The electrodes were placed midway between the iliac crest and the greater trochanter with an inter-interelectrode distance of

20 mm.[11] Before attaching the electrodes, the skin cleaning of with alcohol on the electrode positions. The signal was digitized at 1,000 Hz, full-wave rectified, and filtered (bandwidth 25–300 Hz).

Each recorded EMG signal was divided in intervals of 15 s. The median frequency of the EMG power spectrum was calculated with fast Fourier transforms (FFT) using the EMG SMART software, which allowed to transform the EMG signal in the time-domain to the frequency-domain.[11] The median frequency was defined as the frequency that divided the spectrum into two equal areas.[11] Linear regression analyses were performed for each subject on the calculated median frequencies as a function of time (Figure 2). The median frequency slope (MF_{slope}) was determined as the slope of the regression line. Moreover, similarly to Kankaanpää et al[14] who analyzed participants in a similar period of time, linear regression analyses were also performed for each subject in the first 75 seconds of the test. The median frequency slope for this period (MF_{slope} 75s) was determined as the slope of the regression line.

Statistical analysis

The test-retest reliability of the HAIE test was calculated with a two-way random model intraclass correlation coefficient (ICC2,1). Reliability coefficients was considered to be poor for an ICC less than 0.51, moderate between 0.51 and 0.70, good between 0.70 and 0.90 and very good for an ICC greater than 0.90.[7] To determine consistency of measurements, the standard error of measurement (SEM) was calculated as $SD \times \sqrt{1\text{-}ICC}$, where SD is the standard deviation of all scores from the participants.[8] The minimal detectable change (MDC) was calculated as $SEM \times 1.96 \times \sqrt{2}$ to construct a 95% CI.[8] The Wilcoxon test was used to assess systematic difference in the rate of perceived exertion between both sessions.

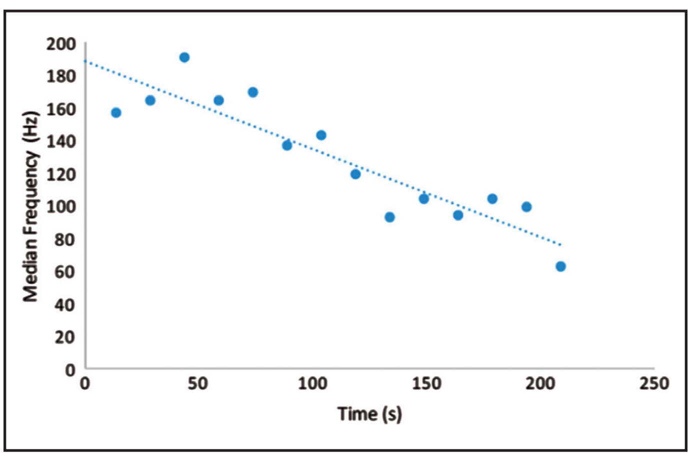

Figure 2. *Median EMG frequency (transformed from time-domain via EMG START software) of the gluteus medius plotted as a function of time for one subject (Subject 3).*

Concerning the validity of the HAIE test, a one-way analysis of variance with repeated measures design (ANOVA) was conducted to determine if the average median frequency (AMF) of participants decreased significantly over time. In order to have the same number of observations in each group, only the last four intervals of 15 seconds were compared. Tukey's post hoc test was used to examine differences between AMF of intervals.

Pearson correlation coefficients were calculated between MF_{slope} and endurance time and between MF_{slope}75s and endurance time. Correlation was defined as weak (< 0.3), moderate (0.3-0.5) and strong (> 0.7).[12]

The statistical analyses were performed using IBM SPSS 23 software (IBM Corp, Armonk, NY, USA) with a significance level of $p < 0.05$.

RESULTS

Test-retest reliability

Descriptive statistics and data for the test-retest reliability (ICC, SEM and MDC) are presented in Table 2. The HAIE test demonstrated good test-retest reliability (ICC = 0.84). The SEM was 11.5 seconds for isometric endurance test and the MDC was 32.8 seconds. No statistically significant differences were found in Borg RPE at the end of the test between two sessions ($p = 0.49$).

Validity

Descriptive statistics are reported in Table 3.

Significant differences were noted between the AMF of participants for the last four 15s intervals ($p = 0.02$). The AMF of intervals 1 and 3 were significantly different ($p > 0.05$) and the AMF of interval 4 was significantly different from the AMF of the intervals 1, 2 and 3 ($p < 0.001$) (Figure 3).

Moderate correlation between MF_{slope} and endurance time ($r = 0.56$, $p = 0.008$) and strong correlation

Table 2. *Descriptive statistics and data for the test-retest reliability of the Hip Abductor Isometric Endurance (HAIE) test (n = 52).*

	Session 1	Session 2
Endurance time (s)		
Mean	104.6	108.2
SD	32.8	36.9
Min	34	38
Max	182	212
Borg RPE		
Mean	19.5	19.4
SD	0.7	0.6
Min	17	17
Max	20	20
ICC (95% CI)	0.84 (0.67-0.92)	
SEM (s)	11.5	
MDC (s)	32.8	

SD= standard deviation; Min= minimum; Max= maximum; Borg RPE= Borg Rating of Perceived Exertion Scale; ICC= intra class correlation coefficient; SEM= standard error of measurement; MDC= minimal detectable change

Table 3. *Descriptive statistics for subjects on the Hip Abductor Isometric Endurance (HAIE) test, rates of perceived exertion, and median frequency slopes (n = 10).*

	HAIE test (s)	Borg RPE	MF_{slope}	MF_{slope} 75s
Subject 1	137	20	- 0.49	- 0.16
Subject 2	81	20	- 0.46	- 0.46
Subject 3	212	20	- 0.54	0.17
Subject 4	91	20	- 0.82	- 0.88
Subject 5	107	20	- 0.66	- 0.02
Subject 6	97	20	- 0.82	- 0.05
Subject 7	109	20	- 0.83	- 0.27
Subject 8	77	20	- 1.17	- 0.67
Subject 9	72	17	- 1.37	- 0.52
Subject 10	95	20	- 0,90	- 0.42
Mean	107.8	19.7	- 0.81	- 0.32
SD	41.1	0.9	0.29	0.31

SD= standard deviation; MF= median frequency

between MF_{slope}75s and endurance time (r = 0.71, p = 0.001) were found.

DISCUSSION

The HAIE test is derived from a previous test described by Van Cant et al.[9] These authors assessed its test-retest reliability and the test demonstrated good intraclass correlation coefficient (ICC = 0.73). However, standard error of measurement (SEM) and minimal detectable change (MDC) were 19.8 and 54.9 seconds, respectively. Thus, the clinical utility of the previously described test for therapists who want to evaluate endurance of hip abductor was questionable, taking account of the MDC. Therefore, in order to increase the test-retest reliability, a few methodological differences were incorporated between the endurance test used in the previous study[9] and the currently described HAIE test: the pelvis was stabilized by straps and in order to control for the horizontality of the leg; a horizontal bar, fixed

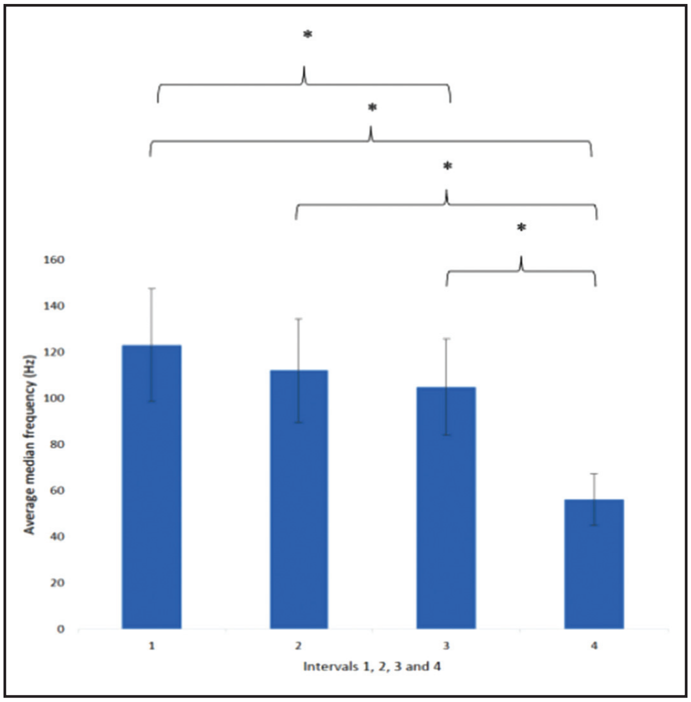

Figure 3. *Average median frequencies of the gluteus medius of the participants for the last four intervals of 15 seconds (intervals 1, 2, 3 and 4).*
** $p < 0.05$.*

to vertical bars, was placed underneath the malleolus and a mirror was positioned close to the examination table so that the participants could monitor and attempt to control the horizontal position of the limb during the test. These modifications could explain the better test-retest reliability of the HAIE test and, therefore, the use of this inexpensive equipment is strongly recommended (bars, straps and mirror) in order to complete the test as accurately as possible in clinical practice.

One of the purposes of this study was to assess the validity of the HAIE test. The results of the present study showed significant decrease of the median frequency of the GMed during the hip abductor isometric endurance test, confirming that fatigue occurs in the Gmed during the test.

Changes in median frequency have been quite frequently used to quantify muscles fatigability in the literature.[5,11,12,13,14] Bigland-Ritchie et al[3] argued that slow-twitch muscle fibers have low-frequency signals, whereas fast-twitch fibers have higher-frequency signals. During fatiguing efforts, fast-twitch fatigue become fatigued and more emphasis is placed on slow-twitch fibers.[5]

At this stage, only two studies have evaluated the fatigability characteristics of Gmed during a fatigue protocol.[5,15] Jacobs et al[5] reported higher AMF than previously reported values associated with trunk extensor muscle. These authors hypothesized that Gmed has larger proportion of fast-twitch fibers than the primarily tonic trunk extensor muscle. In our study, the AMF of the first interval of 15 seconds (142.2 +/- 16.8 Hz) was comparable with AMF of the initial epoch reported by Jacobs et al (2) (146.2 +/- 24.2 Hz). In comparison, Elfving et al[18] found lesser AMF values associated with the trunk extensors muscle (53.2 Hz).

In the present study, similarly to Jacobs et al[5], analyses of hip abductor muscles fatigue have relied on EMG data collected from the Gmed only. Nevertheless, the hip abductors are composed of several muscles that act synergistically to produce hip abduction. In a systematic review, Neumann[19] analyzed the actions of the muscles of the hip and reported that the primary hip abductor muscles include all fibers of the Gmed and gluteus minimus, as well as the tensor fasciae latae. The piriformis, sartorius and rectus femoris are considered secondary hip abductors. Furthermore, Coorevits et al[11] suggest that it is important to simultaneously measure several muscle locations in order to avoid an oversimplified view of the EMG muscle performance. Moreover, during the test it was also possible that the trunk muscles and the contralateral hip abductor muscles were activated. Widler et al[16] reported that there is considerable activation of the contralateral-to-ipsilateral Gmed when evaluated in three different testing positions designed to assess unilateral hip abductor muscle. This suggests that bilateral activation is inevitable during the test.

Despite these considerations, the present study showed moderate and strong correlations between MF_{slope} and endurance time. The MF_{slope} values represent the shift from higher- to lower-frequency motor units.[5] The correlation between MF_{slope} and endurance time indicate that muscle fatigue of the Gmed can partially explain the test endurance time. In other words, if a subject demonstrated a steeper negative MF_{slope}, the Gmed was fatigued at a faster rate during the test and endurance time was lower.

MF_{slope} was calculated throughout the entire test for each subject and, also, in the first 75 seconds of the test. According to Kankaanpää et al[14], the hypothesis was that analyzing participants in a same period of time could a better way to discriminate test performance and, therefore, that the best performers should demonstrate a less-steep slope in the first 75 seconds rather than throughout the entire test. This may explain why moderate correlation was found between MF_{slope} and endurance time and strong correlation between MF_{slope}75s and endurance time. Further research is needed to determine if the analyze of participants in a same period of time rather than throughout the entire test is more appropriate.

The validity and the reliability of the EMG spectrum analysis to monitor muscle fatigue has been evaluated in several studies. Mutchler et al[15] sought to determine the reliability of the median frequency measure between two sessions of a 60 s standing isometric endurance protocol. The ICC-values demonstrated that median frequency measurements of hip muscles, including Gmed, were found to have suitable reliability. Mannion et al[20] concluded that measurement of the rate of decline in median frequency of the surface EMG power spectrum provides an excellent technique for objectively monitoring the fatigability of the trunk extensors.

The present study must be considered in the light of several limitations. First, the participants assessed were healthy females and the results should not be generalized to males or unhealthy or injured females. Second, at the second session, the investigators were not blinded from prior data and bias might have been introduced during evaluation. Third, analyses of muscle fatigue have relied on EMG from the Gmed only. Thus, it is possible that other hip abductor muscles also contribute to abduction endurance and may account for performance during the HAIE test. Finally, at this stage, no consensus exists on the best way to evaluate muscle fatigue using EMG spectrum analysis and validity of the measure used herein has not been evaluated in Gmed. This may constitute the object of future studies.

CONCLUSION

The results from this study support that the HAIE test is a reliable test for evaluating the endurance of the hip abductors. Further investigations should continue to explore the validity of the test, especially to determine which muscles limit the endurance time in healthy and unhealthy/injured subjects.

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